

**Total Ionizing Dose Test Report:
TL431 Three Terminal Adjustable Voltage Regulator (Texas Instruments)**

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1. Introduction

A total dose test was performed in January 2007 to characterize the TL431, a three-terminal voltage regulator. The manufacturer is Texas Instruments and the part will be used on NASA's Solar Dynamic Observatory. Since the expected dose in space is less than 10 krad(Si), radiation exposure was halted after a total dose of 20 krad(Si).

2. Device Description

Table I shows the relevant device and test information for the TL431. Fig. 1 is a functional block diagram of the device.

Table I.
TL431 Device and Test Information

Generic Part Number:	TL431
Full Part Number	TL431
Manufacturer:	Texas Instruments
Lot Date Code (LDC):	No information as package at GSFC
Quantity Tested:	6
Serial Numbers of Control Sample:	1
Serial Numbers of Radiation Samples:	2, 3, 4, 5, 6
Part Function:	Adjustable precision shunt regulator
Part Technology:	Bipolar
Package Style:	16 pin TO can
Test Equipment:	Parametric Analyzer, dual power supply
Test Engineer:	Forney
Dose Levels (krad (Si))	0, 5, 10, 15, and 20
Target dose rate (rad (Si)/sec)	0.02 rads/sec

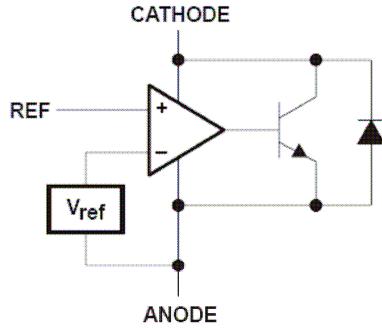


Fig. 1. Functional Block Diagram of the TL431.

3. Test Method

Six devices were tested; five were exposed to gamma rays in the NASA-GSFC Co⁶⁰ cell and the sixth was used as a control. The dose rate was 0.02 rad(Si)/s. This is higher than the dose rate recommended for ELDRS testing (0.01 rad(Si)/s). Previous testing of the part at 0.02 rad(Si)/s indicated that the parametric values did not change up to 20 krad(Si) so we felt justified in using the higher rate in order to reduce the amount of time required to complete the test. The parts were irradiated at room temperature and, after each incremental dose (5, 10, 15, and 20 krad(Si)), the parts were electrically tested for functionality and for parametric degradation.

The following electrical parameters were measured:

- V_{ref} (reference voltage)
- $\Delta V_{ref}/\Delta V_{KA}$ (ratio of change in reference voltage to change in cathode voltage)
- I_{ref} (Reference Current)
- I_{min} (minimum cathode current for regulation)
- I_{off} (Off-state cathode current)

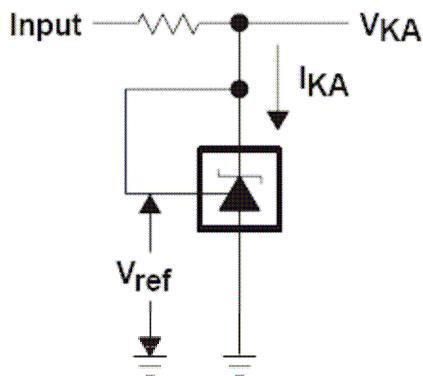


Fig. 2. Test setup for measuring V_{ref} (the voltage between anode and cathode) and I_{min} (the minimum cathode current for regulation). V_{ref} was measured with the cathode current (I_{KA}) set to 10 mA. This required the proper selection of resistor value. I_{min} was obtained by reducing the input voltage until the part was no longer in regulation. I_{min} is then equal to I_{KA} when regulation ceases.

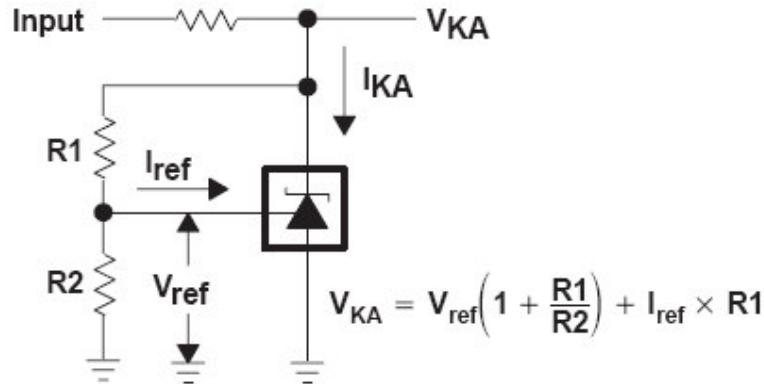


Fig. 3. Test setup used for measuring I_{ref} and $|Z_{KA}|$. R_1 was set to $10\text{ k}\Omega$ and R_2 was set to ∞ .

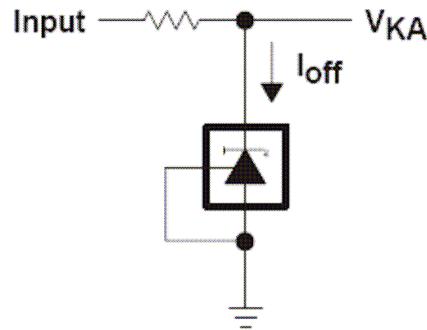


Fig. 4. Test setup used for measuring I_{off} , the off-state cathode current. V_{KA} was set to 36 V and V_{ref} was set to 0 V.

4. Results

The results for the measurements of the above parameters are listed in the following tables:

Table II
 V_{ref} (V) measured using the circuit in Fig. 2.
 (Specifications $2.44\text{ V} < V_{ref} < 2.55\text{ V}$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	2.519	2.523	2.509	2.525	2.512	2.509	2.509	2.52	2.515	7.034E-03
5	x	2.522	2.509	x	2.512	2.509	2.509	2.519	2.512	5.630E-03
10	2.519	2.523	2.504	x	2.513	2.509	2.509	2.519	2.513	7.055E-03
15	2.519	2.523	2.504	x	2.513	2.508	2.509	2.519	2.513	7.174E-03
20	2.519	2.523	2.506	x	2.513	2.509	2.509	2.519	2.513	6.585E-03

Table III
 $I_{ref}(\mu A)$ measured using the circuit in Fig. 3.
 (Specification: $I_{ref} < 4 \mu A$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	2.0	2.1	1.7	2.0	2.0	2.0	2.0	2.0	1.971	1.254E-01
5	x	2.3	1.9	x	2.3	2.2	2.2	2.2	2.180	1.643E-01
10	2.4	2.5	2.0	x	2.4	2.5	2.5	2.5	2.383	1.941E-01
15	2.5	2.4	2.1	x	2.4	2.4	2.4	2.4	2.367	1.366E-01
20	2.5	2.6	2.1	x	2.5	2.5	2.5	2.4	2.450	1.761E-01

Table IV
 $I_{min}(\mu A)$ measured using circuit in Fig. 2.
 (Specification: $I_{min} < 1000 \mu A$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	746	750	750	740	742	741	749	748	745.429	4.392E+00
5	x	749	750	x	749	742	747	748	747.400	3.209E+00
10	748	752	755	x	750	745	751	748	750.167	3.430E+00
15	746	748	754	x	752	743	748	748	748.500	3.987E+00
20	751	750	748	x	748	748	750	750	749.167	1.329E+00

Table V
 $I_{off}(\mu A)$ measured using circuit in Fig. 4.
 (Specification: $I_{off} < 1 \mu A$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.020	0.000E+00
5	x	0.02	0.02	x	0.02	0.02	0.02	0.021	0.020	0.000E+00
10	0.01	0.01	0.01	x	0.01	0.01	0.01	0.01	0.010	0.000E+00
15	0.006	0.006	0.008	x	0.01	0.01	0.01	0.01	0.008	1.966E-03
20	0.01	0.01	0.01	x	0.01	0.014	0.01	0.01	0.011	1.633E-03

Table VI
 $\Delta V_{ref}/\Delta V_{KA}$ (mV/V) measured using circuit in Fig. 3 for $V_{KA} = (10V - V_{ref})$.
 (Specification: $< -2.7 \text{ mV/V}$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	-8.020E-01	-8.025E-01	-1.335E+00	x	-6.677E-01	-6.675E-01	-6.675E-01	-8.021E-01	-0.824	2.590E-01
5	x	-6.686E-01	-1.335E+00	x	-6.677E-01	-6.675E-01	-6.675E-01	-6.684E-01	-0.801	2.983E-01
10	-8.020E-01	-8.025E-01	-8.004E-01	x	-8.014E-01	-8.010E-01	-8.010E-01	-6.684E-01	-0.801	7.553E-04
15	-8.020E-01	-8.025E-01	-6.670E-01	x	-8.014E-01	-8.009E-01	-8.010E-01	-6.684E-01	-0.779	5.492E-02
20	-6.684E-01	-8.025E-01	-8.006E-01	x	-8.014E-01	-8.010E-01	-8.010E-01	-6.684E-01	-0.779	5.427E-02

Table VII
 $\Delta V_{ref}/\Delta V_{KA}$ (mV/V) measured using circuit in Fig. 3 for $V_{KA} = (36V-10V)$.
 (Specification: $< -2.0 \text{ mV/V}$)

TID	DUT7	DUT8	DUT9	DUT10	DUT11	DUT12	DUT13	Control	Average	St. Dev
0	-7.308E-01	-7.692E-01	-9.231E-01	x	-7.308E-01	-7.308E-01	-7.308E-01	-7.692E-01	-0.769	7.692E-02
5	x	-7.308E-01	-9.615E-01	x	-7.308E-01	-7.692E-01	-7.692E-01	-7.308E-01	-0.792	9.654E-02
10	-7.692E-01	-7.692E-01	-7.692E-01	x	-7.692E-01	-7.692E-01	-7.692E-01	-7.308E-01	-0.769	1.333E-08
15	-7.692E-01	-7.692E-01	-7.692E-01	x	-7.692E-01	-7.692E-01	-7.692E-01	-7.308E-01	-0.769	1.333E-08
20	-7.692E-01	-8.077E-01	-8.077E-01	x	-7.692E-01	-8.077E-01	-7.692E-01	-7.308E-01	-0.788	2.107E-02

5. Conclusions

All TL431 parts passed all functional and parametric electrical tests up to a total dose of 20 krad(Si).